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(54) Title: AN HSP70 PEPTIDE STIMULATING NATURAL KILLER (NK) CELL ACTIVITY AND USES THEREOF

(57) Abstract: The present invention relates to an immunostimulatory peptide derived from an Hsp70 protein and peptides comprising said immunostimulatory peptide. Furthermore the present invention pertains to polynucleotides encoding said peptide, vectors comprising said polynucleotides, fusion (poly)peptides comprising said peptide and compositions comprising said peptide. In addition the present invention relates to the use of said peptide, polynucleotide, vector or fusion (poly)peptide, for the preparation of pharmaceutical compositions for the treatment of diseases and for the stimulation of natural killer cell (NK cell) activity.

An Hsp70 peptide stimulating Natural Killer (NK) cell activity and uses thereof

The present invention relates to an immunostimulatory peptide derived from an Hsp70 protein and peptides comprising said immunostimulatory peptide. Furthermore the present invention pertains to polynucleotides encoding said peptide, vectors comprising said polynucleotides, fusion (poly)peptides comprising said peptide and compositions comprising said peptide. In addition the present invention relates to the use of said peptide, polynucleotide, vector or fusion (poly)peptide, for the preparation of pharmaceutical compositions for the treatment of diseases and for the stimulation of natural killer cell (NK cell) activity.

Several documents are cited throughout the text of this specification. The disclosure content of each of the documents cited herein (including any manufacturer's specifications, instructions, etc.) is herewith incorporated herein by reference.

Heat shock proteins (HSP) are highly conserved proteins that are inducible by a variety of stressful stimuli and by physiological processes including cell differentiation and development (Lindquist and Craig. 1988). Intracellular HSP function as molecular chaperones, they are involved in protein folding, transport, antigen processing and presentation (DeNagel and Pierce, 1992; Hartl, 1996). HSP with a molecular weight of 70 and 90 kDa also have been shown to function as carrier proteins for immunogenic tumor-derived peptides that induce a T cell mediated immune response against cancer (Tamura et al., 1997; Schild et al., 1999; Srivastava et al., 1998). Antigen presenting cells are key for the receptor mediated uptake of HSP-peptide complexes (Arnold-Schild et al., 1999) Several groups reported an unusual plasma membrane localization of HSP on tumor cells (Altmeyer et al., 1996; Ferrarini et al., 1992; Piselli et al., 1995; Tamura et al., 1993). The inventors were the first who demonstrated that NK cells also have to be considered as relevant effector cells for the recognition of membrane-bound Hsp70 on tumor cells (Multhoff et al., 1995a, 1995b; Multhoff et al., 1997; Botzler et al., 1996a, 1996b). With respect to these findings and due to the fact that normal cells lack

expression of Hsp70, the inducible member of the Hsp70 group on the plasma membrane, one might speculate that Hsp70 acts as a tumor-selective recognition structure for NK cells. Antibody blocking studies revealed that Hsp70 is a relevant recognition structure for transiently plastic adherent NK cells (Multhoff et al., 1995a, 1995b; Multhoff et al., 1997; Botzler et al., 1998). Although several antibodies detect membrane-bound Hsp70 on tumor cells, only the mAb RPN1197 was able to block the cytolytic activity of NK cells (Multhoff et al. 1995a).
It was recently demonstrated that proliferation and cytolytic activity of NK cells against Hsp70-expressing tumor cells could be stimulated with recombinant Hsp70 protein but not with Hsc70 or DnaK (Multhoff et al. 1999). As target cells for the cytolytic activity of NK cells the tumor sublines CX+ and CX- with an identical MHC and adhesion molecule expression pattern that differ with respect to the capacity to express Hsp70 on the plasma membrane, were used (Multhoff et al. 1997). It was furthermore demonstrated that not only intact Hsp70 protein but also the C-terminal domain of Hsp70hom activates NK cells. Hsp70hom, a testis specific member of the Hsp70 family, is 94% homologous to the C-terminal domain of Hsp70.

For the production of a (poly)peptide and its formulation in pharmaceutical compositions it is generally desirable to reduce its size as far as is reasonable with respect to its biological activity. A reduction in size and complexity increases the yield of a recombinantly expressed peptide and generally increases its chemical stability. When producing a peptide synthetically, yield and reliability of the process are also increased with a peptide of reduced size whereas production cost is minimized.

Therefore the technical problem underlying the present invention was to provide a small, easily obtainable molecule with immunostimulatory activity which can be produced synthetically or recombinantly in large amounts and at low cost. The solution to said technical problem is achieved by providing the embodiments characterized in the claims.

Accordingly, the present invention provides a peptide comprising or having the amino acid sequence TKDNNLLGRFELXG wherein X is T or S, wherein S is

preferred (also throughout the further embodiments recited in this specification). The invention also encompasses fragments or derivatives of said peptide which will be explained further below.

The tem “peptide” as used herein denotes amino acid sequences comprising 30 or less amino acids.

It has surprisingly been found that a peptide comprising or having the sequence TKDNNLLGRFELXG, wherein X is T or S, wherein S is preferred, is sufficient for the stimulation of NK cell activation. At least for in vitro purposes, an advantageous final concentration of the peptides has been found to be in the range of 0.2 to 2.5 µg/ml.

From the data available from the prior art it was not deducible that a peptide structure that encompasses hardly more than an antibody binding epitope might trigger such a complex cascade of events. In contrast, it was generally believed that a peptide alone is not sufficient to trigger T cell activation. The size of the structure that was found sufficient to trigger such events excludes that cross-linking events are involved in the stimulation of NK activity by the underlying mechanism which, again, is surprising in view of the general beliefs of the prior art.

Comprised by the invention are also fragments and derivatives of the peptide of the invention wherein the derivatives have a different amino acid sequence which deviates from that of the peptide of the invention by substitution, insertion, deletion, duplication, inversion etc. provided that said fragments or derivatives stimulate NK cell activation. It is most preferred that in these peptides, amino acids TKDN in positions 450 to 453 (of Hsp70) R in position 458 and S in position 462 are retained. Said derivatives or fragments may be further derivatized by e.g. peptidomimetics as will be outlined below. They may also form part of a fusion protein as described below. The derivatives and fragments that are composed by the present invention may be tested, without undue burden for functionality and medical usefulness as described throughout this specification and as described in particular in the appended examples. The derivatives or fragments preferably have the length of at least 13 amino acids and are preferably not longer than 30 amino acids, more

preferably not longer than 20 amino acids.

The present invention also relates a peptide as defined supra comprising or having the amino acid sequence EGERAMTKDNNLLGRFELXG wherein X is T or S. The invention also encompasses fragments or derivatives of said peptide which have the activation function and can be selected as described supra.

The peptide of the present invention may be linked to other (poly)peptide sequences or may be part of (a) fusion (poly)peptide(s). Such fusion (poly)peptides/ fusionproteins may be engineered to improve the characteristics of said fragments, derivatives or variants. For example, further amino acids may be added to improve stability and/or persistence during purification, handling or storage processes or to improve stability, half-life and/or persistence in vitro and in host organisms and/or patients. Furthermore, the peptide of the invention may be fused to other proteins or peptides which play a role in immune responses or in their potential treatment. Within the scope of the present invention are also molecules which comprise the peptide of the invention which are linked to marker molecules and/or marker amino acid sequences. Such sequences comprise but are not limited to peptide-tags, histidine-tags, fluorescence molecules, GFP, FLAG and GST.

Therefore, the invention furthermore relates to a fusion (poly)peptide comprising the peptide of the invention.

The invention also relates to a polynucleotide encoding the peptide of the invention or said fusion (poly)peptide comprising the peptide of the invention.

The polynucleotide as employed in accordance with this invention and encoding the above-described peptide may be, e.g., DNA, cDNA, RNA or synthetically produced DNA or RNA or a recombinantly produced chimeric nucleic acid molecule comprising any of those polynucleotides either alone or in combination.

In a further embodiment, the invention relates to a nucleic acid molecule of at least 15 nucleotides in length hybridizing with a polynucleotide as described above or with

a complementary strand thereof. Specific hybridization occurs preferably under stringent conditions and implies no or very little cross-hybridization with nucleotide sequences encoding no or substantially different peptides. Such nucleic acid molecules may be used as probes and/or for the control of gene expression. Nucleic acid probe technology is well known to those skilled in the art who will readily appreciate that such probes may vary in length. Preferred are nucleic acid probes of 17 to 35 nucleotides in length. Of course, it may also be appropriate to use nucleic acids of up to 100 and more nucleotides in length. Therefore, the polynucleotides encoding the peptide of the invention may be used as nucleic acid probes to identify nucleic acids molecules encoding (poly)peptides different from HSP70 comprising the peptide of the invention. Such (poly)peptides may be useful tools for investigating different pathways which may be involved in the activation of NK cells. Said nucleic acid probes are also useful for various pharmaceutical and/or diagnostic applications. On the one hand, they may be used as PCR primers for the amplification of polynucleotides encoding the peptide of the invention. In this context they may serve as useful diagnostic tools to determine e.g. the expression level of (poly)peptides comprising the peptide of the invention thereby assessing or predicting the status of NK cell activity. Nucleic acid molecules employed in this preferred embodiment of the invention which are complementary to a polynucleotide as described above may also be used for repression of expression of a gene comprising such a polynucleotide, for example due to an antisense or triple helix effect or for the construction of appropriate ribozymes (see, e.g., EP-A1 0 291 533, EP A1 0 321 201, EP-A2 0 360 257) which specifically cleave the (pre)-mRNA of a gene comprising a polynucleotide as described herein above. Selection of appropriate target sites and corresponding ribozymes can be done as described for example in Steinecke, Ribozymes, Methods in Cell Biology 50, Galbraith et al. eds Academic Press, Inc. (1995), 449-460. Standard methods relating to antisense technology have also been described (Melani, Cancer Res. (1991), 2897-2901). Said antisense or triple helix effect as well as the construction of relevant ribozymes is/are partially useful in pharmaceutical compositions to be employed for the suppression of NK-cell activity, e.g., in autoimmune or inflammatory diseases, viral infections, sepsis, etc. Furthermore, the person skilled in the art is well aware that it is also possible to label such a nucleic acid probe with an appropriate marker for

specific (Inter alia, diagnostic) applications, such as for the detection of the presence of a polynucleotide as described herein above in a sample derived from an organism.
The above described nucleic acid molecules may either be DNA or RNA or a hybrid thereof. Furthermore, said nucleic acid molecule may either contain, for example, thioester bonds and/or nucleotide analogues, commonly used in oligonucleotide anti-sense approaches. Said modifications may be useful for the stabilization of the nucleic acid molecule against endo- and/or exonucleases in the cell. Said nucleic acid molecules may be transcribed by an appropriate vector containing a chimeric gene which allows for the transcription of said nucleic acid molecule in the cell.

With respect to the nucleotide sequences characterized above, the term "hybridizing" in this context is understood as referring to conventional hybridization conditions, preferably such as hybridization in 50%formamide/6×SSC/0.1%SDS/100μg/ml ssDNA, in which temperatures for hybridization are above 37°C and temperatures for washing in 0.1xSSC/0.1%SDS are above 55°C. Most preferably, the term "hybridizing" refers to stringent hybridization conditions, for example such as described in Sambrook, Molecular Cloning A Laboratory Manual, Cold Spring Harbor Laboratory (1989) N.Y. Stringent hybridization conditions include hybridization at 65°C in 0.2 x SSC, 0.1% SDS.

In a further embodiment the invention pertains to a vector comprising the polynucleotide encoding the peptide of the invention.

Many suitable vectors are known to those skilled in molecular biology, the choice of which would depend on the function desired and include plasmids, cosmids, viruses, bacteriophages and other vectors used conventionally in genetic engineering. Methods which are well known to those skilled in the art can be used to construct various plasmids and vectors; see, for example, the techniques described in Sambrook, Molecular Cloning A Laboratory Manual, Cold Spring Harbor Laboratory (1989) N.Y. and Ausubel, Current Protocols in Molecular Biology, Green Publishing Associates and Wiley Interscience, N.Y. (1989), (1994). Alternatively, the polynucleotides and vectors of the invention can be reconstituted into liposomes for

delivery to target cells. As discussed in further details below, a cloning vector was used to isolate individual sequences of DNA. Relevant sequences can be transferred into expression vectors where expression of a particular polypeptide is required. Typical cloning vectors include pBscpt sk, pGEM, pUC9, pBR322 and pGBT9. Typical expression vectors include pTRE, pCAL-n-EK, pESP-1, pOP13CAT.

Hence, in a preferred embodiment of the present invention the polynucleotides encoding the peptide of the invention either alone or present in a vector are linked to control sequences which allow the expression of the polynucleotide in prokaryotic and/or eukaryotic cells.

The term "control sequence" refers to regulatory DNA sequences which are necessary to effect the expression of coding sequences to which they are ligated. The nature of such control sequences differs depending upon the host organism. In prokaryotes, control sequences generally include promoter, ribosomal binding site, and terminators. In eukaryotes generally control sequences include promoters, terminators and, in some instances, enhancers, transactivators or transcription factors. The term "control sequence" is intended to include, at a minimum, all components the presence of which are necessary for expression, and may also include additional advantageous components.

The term "operably linked" refers to a juxtaposition wherein the components so described are in a relationship permitting them to function in their intended manner. A control sequence "operably linked" to a coding sequence is ligated in such a way that expression of the coding sequence is achieved under conditions compatible with the control sequences. In case the control sequence is a promoter, it is obvious for a skilled person that double-stranded nucleic acid is preferably used.

Thus, the vector of the invention is preferably an expression vector. An "expression vector" is a construct that can be used to transform a selected host cell and provides for expression of a coding sequence in the selected host. Expression vectors can for instance be cloning vectors, binary vectors or integrating vectors. Expression comprises transcription of the nucleic acid molecule preferably into a translatable mRNA. Regulatory elements ensuring expression in prokaryotic and/or eukaryotic cells are well known to those skilled in the art. In the case of eukaryotic cells they

comprise normally promoters ensuring initiation of transcription and optionally poly-A signals ensuring termination of transcription and stabilization of the transcript. Possible regulatory elements permitting expression in prokaryotic host cells comprise, e.g., the P_L, lac, trp or tac promoter in E. coli, and examples of regulatory elements permitting expression in eukaryotic host cells are the AOX1 or GAL1 promoter in yeast or the CMV-, SV40-, RSV-promoter (Rous sarcoma virus), CMV-enhancer, SV40-enhancer or a globin intron in mammalian and other animal cells. In this context, suitable expression vectors are known in the art such as Okayama-Berg cDNA expression vector pcDV1 (Pharmacia), pCDM8, pRc/CMV, pcDNA1, pcDNA3 (In-vitrogene), pSPORT1 (GIBCO BRL). An alternative expression system which could be used to express a cell cycle interacting protein is an insect system. In one such system, Autographa californica nuclear polyhedrosis virus (AcNPV) is used as a vector to express foreign genes in Spodoptera frugiperda cells or in Trichoplusia larvae. The coding sequence of a nucleic acid molecule of the invention may be cloned into a nonessential region of the virus, such as the polyhedrin gene, and placed under control of the polyhedrin promoter. Successful insertion of said coding sequence will render the polyhedrin gene inactive and produce recombinant virus lacking coat protein. The recombinant viruses are then used to infect S. frugiperda cells or Trichoplusia larvae in which the protein of the invention is expressed (Smith et al., 1983; Engelhard et al., 1994).

To obtain agents derived from the peptide of the present invention with a further increased stability and to improve the uptake via the gastrointestinal tract or other routes different from a parental application like e.g. skin or lung peptidomimetics may be utilized to design pseudopeptide analogues. A computer redesign of the structure of the peptide of the invention can be performed using appropriate computer programs (Olszewski et al., 1996; Hoffman et al., 1995). In particular, the appropriate programs can be used for the identification of interactive sites of the peptide and, if present, its receptor or other interacting proteins by computer assistant searches for complementary peptide sequences (Fassina, 1994). Further appropriate computer systems for the design of protein and peptides are described in the prior art, for example in Berry et al. (1994), Wodak et al., (1987) or Pabo et al. (1986). The results obtained from the above-described computer analysis can be

used for, e.g., the preparation by peptidomimetics of the peptide of the invention. Such pseudopeptide analogues of the natural amino acid sequence of the peptide may very efficiently mimic the parent protein (Benkirane et al., 1996). For example, incorporation of easily available achiral Ω-amino acid residues into the peptide of the invention results in the substitution of amide bonds by polymethylene units of an aliphatic chain, thereby providing a convenient strategy for constructing a peptide by peptidomimetics (Banerjee et al., 1996). Superactive peptidomimetic analogues of small peptide hormones in other systems are described in the prior art (Zhang et al., 1996). Appropriate peptidomimetics of the peptide of the present invention can also be identified by the synthesis of peptidomimetic combinatorial libraries through successive amide alkylation and testing the resulting compounds, e.g., for their immunological properties. Methods for the generation and use of peptidomimetic combinatorial libraries are described in the prior art, for example in Ostresh et al. (1996), and Dorner et al. (1996).
Furthermore, a three-dimensional and/or crystallographic structure of the peptide of the invention can be used for the design of peptidomimetic inhibitors of the biological activity of the protein of the invention (Rose et al., 1996; Rutenber et al., 1996).

The invention therefore also relates to a method of refining the peptide of the invention comprising (a) modeling said peptide by peptidomimetics and (b) chemically synthesizing the modeled peptide. A most suitable starting point for modeling by peptidomimetics is to test libraries of peptides of different lengths and sequences for stimulating NK-cell activation. By determining where (i.e. to which amino acid residues of which protein) the peptide of the invention binds to an NK-cell the crucial amino acids for binding within the peptide of the invention can be identified. In following steps, the peptide of the invention can be optimized by chemical modification so that a more efficient stimulation of NK-cell activation is achieved. Other putative NK cell activators can be modeled in the same way.

In another embodiment the present invention further relates to a composition comprising said peptide or a fragment or derivative thereof the polynucleotide encoding said peptide or a fragment or derivative thereof, a vector comprising said polynucleotide or a fusion (poly)peptide comprising said peptide or a fragment or

derivative thereof and a pharmaceutically acceptable carrier and/or diluent.

The term "composition" as used herein also encompasses medical products and medical adjuvants and vaccines.

According to the invention, medical products are all substances or preparations used individually or in combination with each other of substances, or other subject-matters which, according to the producer, are meant to be applied to humans due to their functions for the purpose of detecting, preventing, monitoring, treating or alleviating diseases and whose main effect in or on the human body is achieved neither by pharmalogically or immunologically effective preparations nor by a metabolism whose effectiveness may well be supported by such preparations.

According to the invention, medical adjuvants are such substances which are used for the production (as active ingredients) of pharmaceutical preparations or compositions.

In a preferred embodiment the composition is a pharmaceutical composition.

Said pharmaceutical composition advantageously also comprises a pharmaceutically acceptable carrier and/or diluent. It is additionally preferred that the pharmaceutical composition recited here or produced in accordance with further embodiments of this invention further comprises IL-2 and/or IL-18 in a suitable dose, preferably in a concentration of 1 ng to 1 µg/ml.

The term pharmaceutically acceptable carrier and/or diluent generally denotes vehicles commonly used to formulate pharmaceutical compositions for animal or human administration. The diluent is selected so as not to affect the biological activity of the combination. Examples of such diluents are sterile distilled water, physiological saline, Ringer's solutions, dextrose solution, Hank's solution, RPMI 1640 Medium and phosphate buffered saline (PBS). In addition, the pharmaceutical composition or formulation may also include other carriers, adjuvants, or nontoxic, nontherapeutic, nonimmunogenic stabilizers and the like. A therapeutically effective dose refers to that amount of protein or its antibodies, antagonists, or inhibitors which ameliorate the symptoms or condition. Therapeutic

efficacy and toxicity of such compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., ED50 (the dose therapeutically effective in 50% of the population) and LD50 (the dose lethal to 50% of the population). The dose ratio between therapeutic and toxic effects is the therapeutic index, and it can be expressed as the ratio, LD50/ED50.

Further examples of suitable pharmaceutical carriers are well known in the art and include phosphate buffered saline solutions, water, emulsions, such as oil/water emulsions, various types of wetting agents, sterile solutions etc. Compositions comprising such carriers can be formulated by well known conventional methods. These pharmaceutical compositions can be administered to the subject at a suitable dose. Administration of the suitable compositions may be effected by different ways, e.g., by intravenous, intraperitoneal, subcutaneous, intramuscular, topical or intradermal administration. The dosage regimen will be determined by the attending physician and clinical factors. As is well known in the medical arts, dosages for any one patient depends upon many factors, including the patient's size, body surface area, age, the particular compound to be administered, sex, time and route of administration, general health, and other drugs being administered concurrently. A typical dose can be, for example, in the range of 0.001 to 1000 µg (or of nucleic acid for expression or for inhibition of expression in this range); however, doses below or above this exemplary range are envisioned, especially considering the aforementioned factors. Generally, the regimen as a regular administration of the pharmaceutical composition should be in the range of 1 µg to 10 mg units per day. If the regimen is a continuous infusion, it should also be in the range of 1 µg to 10 mg units per kilogram of body weight per minute, respectively. Progress can be monitored by periodic assessment.

The compositions comprising, the peptide, compound drug, pro-drug or pharmaceutically acceptable salts thereof may conveniently be administered by any of the routes conventionally used for drug administration, for instance, orally, topically, parenterally or by inhalation. Acceptable salts comprise acetate, methylester, HCL, sulfate, chloride and the like. The drugs may be administered in conventional dosage forms prepared by combining the drugs with standard pharmaceutical carriers according to conventional procedures. The drugs and pro-drugs identified and obtained in accordance with the present invention may also be

administered in conventional dosages in combination with a known, second therapeutically active compound. Such therapeutically active compounds comprise, for example, those mentioned above. These procedures may involve mixing, granulating and compressing or dissolving the ingredients as appropriate to the desired preparation. It will be appreciated that the form and character of the pharmaceutically acceptable character or diluent is dictated by the amount of active ingredient with which it is to be combined, the route of administration and other well-known variables. The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof. The pharmaceutical carrier employed may be, for example, either a solid or liquid. Examplary of solid carriers are lactose, terra alba, sucrose, talc, gelatin, agar, pectin, acacia, magnesium stearate, stearic acid and the like. Exemplary of liquid carriers are phosphate buffered saline solution, syrup, oil such as peanut oil and olive oil, water, enulsions, various types of wetting agents, sterile solutions and the like. Similarly, the carrier or diluent may include time delay material well known to the art, such as glyceryl mono-stearate or glyceryl distearate alone or with a wax.

A wide variety of pharmaceutical forms can be employed. Thus, if a solid carrier is used, the preparation can be tableted, placed in a hard gelatin capsule in powder or pellet form or in the form of a troche or lozenge. The amount of solid carrier will vary widely but preferably will be from about 25 mg to about 1 g. When a liquid carrier is used, the preparation will be in the form of a syrup, emulsion, soft gelatin capsule, sterile injectable liquid such as an ampule or nonaqueaous liquid suspension.

The composition may be administered topically, that is by non-systemic administration. This includes the application externally to the epidermis or the buccal cavity and the instillation of such a compound into the ear, eye and nose, such that compound does not significantly enter the blood stream. In contrast, systemic administration refers to oral, intravenous, intraperitoneal and intramuscular administration.

Formulations suitable for topical administration include liquid or semi-liquid preparations suitable for penetration through the skin to the site of inflammation such as liniments, lotions, creams, ointments or pastes, and drops suitable for administration to the eye, ear or nose. The active ingredient may comprise, for

topical administration, from 0.001% to 10% w/w, for instance from 1% to 2% by weight of the formulation. It may however comprise as much as 10% w/w but preferably will comprise less than 5% w/w, more preferably from 0.1% to 1% w/w of the formulation.

Lotions according to the present invention include those suitable for application to the skin or eye which are suitable, for example, for use in UV protection. An eye lotion may comprise a sterile aqueous solution optionally containing a bactericide and may be prepared by methods similar to those for the preparation of drops. Lotions or liniments for application to the skin may also include an agent to hasten drying and to cool the skin, such as an alcohol or acetone, and/or a moisturizer such as glycerol or an oil such as castor oil or arachis oil.

Creams, ointments or pastes according to the present invention are semi-solid formulations of the active ingredient for external application. They may be made by mixing the active ingredient in finely-divided or powdered form, alone or in solution or suspension in an aqueous or non-aqueous fluid, with the aid of suitable machinery, with a greasy or non-greasy base. The base may comprise hydrocarbons such as hard, soft or liquid paraffin, glycerol, beeswax, a metallic soap; a mucilage; an oil of natural origin such as almond, corn, arachis, castor or olive oil; wool fat or its derivatives or a fatty acid such as steric or oleic acid together with an alcohol such as propylene glycol or a macrogel. The formulation may incorporate any suitable surface active agent such as an anionic, cationic or non-ionic surfactant such as a sorbitan ester or a polyoxyethylene derivative thereof. Suspending agents such as natural gums, cellulose derivatives or inorganic materials such as silicaceous silicas, and other ingredients such as lanolin, may also be included.

Drops according to the present invention may comprise sterile aqueous or oily solutions or suspensions and may be prepared by dissolving the active ingredient in a suitable aqueous solution of a bactericidal and/or fungicidal agent and/or any other suitable preservative, and preferably including a surface active agent. The resulting solution may then be clarified by filtration, transferred to a suitable container which is then sealed and sterilized by autoclaving or maintaining at 98-100°C for half an hour. Alternatively, the solution may be sterilized by filtration and transferred to the container by an aseptic technique. Examples of bactericidal and

fungicidal agents suitable for inclusion in the drops are phenylmercuric nitrate or acetate (0.002%), benzalkonium chloride (0.01%) and chlorhexidine acetate (0.01%). Suitable solvents for the preparation of an oily solution include glycerol, diluted alcohol and propylene glycol.

The composition in accordance with the present invention may be administered parenterally, that is by intravenous, intramuscular, subcutaneous intranasal, intrarectal, intravaginal or intraperitoneal administration. The subcutaneous and intramuscular forms of parenteral administration are generally preferred. Appropriate dosage forms for such administration may be prepared by conventional techniques. The composition may also be administered by inhalation, that is by intranasal and oral inhalation administration. Appropriate dosage forms for such administration, such as an aerosol formulation or a metered dose inhaler, may be prepared by conventional techniques.

For all methods of use disclosed herein for compositions according to the invention, the daily oral dosage regimen will preferably be from about 0.1 to about 80 mg/kg of total body weight, preferably from about 0.2 to 30 mg/kg, more preferably from about 0.5 mg to 15 mg. The daily parenteral dosage regimen about 0.1 to about 80 mg/kg of total body weight, preferably from about 0.2 to about 30 mg/kg, and more preferably from about 0.5 mg to 15 mg/kg. The daily topical dosage regimen will preferably be from 0.1 mg to 150 mg, administered one to four, preferably two to three times daily. The daily inhalation dosage regimen will preferably be from about 0.01 mg/kg to about 1 mg/kg per day. It will also be recognized by one of skill in the art that the optimal quantity and spacing of individual dosages of the compositions will be determined by the nature and extent of the condition being treated, the form, route and site of administration, and the particular patient being treated, and that such optimums can preferably be determined by the methods described herein. It will also be appreciated by one of skill in the art that the optimal course of treatment, i.e., the number of doses of the compositions given per day for a defined number of days, can be ascertained by those skilled in the art using conventional course of treatment determinations tests. The dosage regimen will be determined by the attending physician and other clinical factors. As is well known in the medical arts, dosages for any one patient depends upon many factors, including the patient's

size, body surface area, age, the particular compound to be administered, sex, time and route of administration, general health, and other drugs being administered concurrently. Progress can be monitored by periodic assessment.

In another embodiment, the DNA sequence or vector of the invention, as described above, may be directly administered to a patient in need thereof. This type of administration is generally referred to as DNA vaccination. Routes for administration of gene vaccines are well known in the art and DNA vaccination has been successfully used to elicit alloimmune, anti-tumor and antiidiotype immune responses (Tighe M. et al., 1998). Moreover, inoculation with nucleic acid molecules/DNA has been found to be protective in different modes of viral disease (Fynan, et al., 1993; Boyer, 1997; Webster, et al., 1994; Montgomery et al., 1993; Barry, 1995; Xu and Liew, 1995; Zhong et al., 1996; Luke et al., 1997; Mor, 1998; MacGregor et al., 1998).

The DNA encoding the peptide of the invention used in a pharmaceutical composition as a DNA vaccine may be formulated e.g. as neutral or salt form. Pharmaceutically acceptable salts, such as acid addition salts, and others, are known in the art. DNA vaccines are administered in dosages compatible with the method of formulation, and in such amounts that will be pharmacologically effective for prophylactic or therapeutic treatments. Preferably, the vaccine comprises an expression vector as described herein above.

Typically, vaccines are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in or suspension in liquid prior to injection also may be prepared. The preparation may be emulsified or the protein may be encapsulated in liposomes. The active immunogenic ingredients often are mixed with pharmacologically acceptable excipients which are compatible with the active ingredient. Suitable excipients include but are not limited to water, saline, dextrose, glycerol, ethanol and the like; combinations of these excipients in various amounts also may be used. The vaccine also may contain small amounts of auxiliary substances such as wetting or emulsifying reagents, pH buffering agents, and/or adjuvants which enhance the effectiveness of the vaccine. For example, such adjuvants can include aluminum hydroxide, N-acetyl-muramyl-L-threonyl-D-

isoglutamine (thr-DMP), N-acetyl-nornuramyl-L-alanyl-D-isoglutamine (CGP 11687, also referred to as nor-MDP), N-acetylmuramyul-L-alanyl-D-isoglutaminyl-L-alanine-2-(1'2'-dipalmitoyl-sn-glycero-3-hydroxphaosphoryloxy)-ethylamine (CGP 19835A, also referred to as MTP-PE), and RIBI (MPL + TDM + CWS) in a 2% squalene/Tween-80® emulsion.

The vaccines usually are administered by intravenous or intramuscular injection. Additional formulations which are suitable for other modes of administration include suppositories and, in some cases, oral or nasal formulations. For suppositories, traditional binders and carriers may include but are not limited to polyalkylene glycols or triglycerides. Oral formulation include such normally employed excipients as, for example, pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate and the like. These compositions may take the form of solutions, suspensions, tables, pills, capsules, sustained release formulations or powders and contain about 10% to about 95% of active ingredient, preferably about 25% to about 70%.

The peptide of the invention or a DNA encoding it are administered as a vaccine in a way compatible with the dosage formulation, and in such amounts as will be prophylactically and/or therapeutically effective. The quantity to be adminstered generally is in the range of about 0.2 nanograms to about 500 micrograms of peptide or DNA per dose, and depends upon the subject to be dosed, and the degree of immune-activation sought. Precise amounts of active ingredient required to be administered may also depend upon the judgment of the practitioner and may be unique to each subject. The peptide or DNA may be given in a single or multiple dose schedule. A multiple dose is one in which a primary course of vaccination may be with one to ten separate doses, followed by other doses given at subsequent time intervals required to maintain and/or to reinforce the immune response, for example, at one week to four months for a second dose, and if required by the individual, subsequent dose(s) weekly or monthly. The dosage regimen also will be determined, at least in part, by the need of the individual, and be dependent upon the practitioner's judgment. It is contemplated that the vaccine containing the immunogenic compounds of the invention may be administered in conjunction with

other immunoregulatory agents, for example, with immunoglobulins or with cytokines.

In another embodiment the method of the invention relates to a method of producing a immunostimulatory peptide comprising

(a) mutating on the DNA or amino acid level a DNA molecule encoding or peptide comprising the sequence TKDNNLLGRFELXG, wherein X is T or S, in one or more nucleotide or amino acid positions;
(b) testing the proliferative response of NK cells to stimulation with IL-2 and/or IL-18 together with the mutated peptide;
(c) comparing the proliferative response of NK cells to IL-2 and/or IL-18 together with the mutated peptide to the proliferative response to IL-2 and/or IL-18 without the mutated peptide or with a peptide having the sequence recited in (a);
(d) selecting a peptide comprising the mutated sequence or a recombinant DNA molecule coding for a peptide comprising the mutated sequence, wherein said mutated peptide displays an increase in the proliferative response as compared to IL-2 and/or IL-18 without the mutated peptide or with a sequence recited in (a) in step (c).

If nucleotides are mutated (i.e. exchanged by different naturally or not naturally occurring nucleotides), it is understood that at least one exchange should lead to an exchange on the amino acid level. It is most preferred that in these peptides, amino acids TKDN in positions 450 to 453 (of Hsp70) R in position 458 and S in position 462 are retained.

The term "proliferative response of NK cells" as used herein denotes proliferation of an NK cell population which can be determined by standard proliferation assays. Such assays comprise the measurement of incorporation of bromodeoxyuridine (BrdU) or thymidine into the cellular genome during S-phase as mentioned in the examples below. The percentage of increase should at least be 10%, preferably at least 20%, more preferably at least 50%. If the proliferative response of the mutated peptide is compared to the peptide having the sequence recited in (a), and an increase is observed, then a compound with an improved stimulatory activity may be selected.

In the method of the invention, the DNA sequence may be mutated upon which the peptide is expressed in a recombinant host such as E. coli, a mammalian or other cell. For this, the DNA sequence is usually expressed in a vector.

In a further embodiment the product is refined by computer redesign and/or peptidomimetics.

The invention also relates to a method of producing a pharmaceutical composition, medical product, medical adjuvant or vaccine comprising the step of formulating the peptide or recombinant DNA molecule selected by the method of the invention with a pharmaceutically acceptable carrier and/or diluent.

The invention further relates to a method of producing a pharmaceutical composition comprising a molecule stimulating the activation of NK cells comprising the steps of (a) modifying the peptide of the invention as a lead compound to achieve (i) modified site of action, spectrum of activity, organ specificity, and/or (ii) improved potency, and/or (iii) decreased toxicity (improved therapeutic index), and/or (iv) decreased side effects, and/or (v) modified onset of therapeutic action, duration of effect, and/or (vi) modified pharmakinetic parameters (resorption, distribution, metabolism and excretion), and/or (vii) modified physico-chemical parameters (solubility, hygroscopicity, color, taste, odor, stability, state), and/or (viii) improved general specificity, organ/tissue specificity, and/or (ix) optimized application form and route by (i) esterification of carboxyl groups, or (ii) esterification of hydroxyl groups with carbon acids, or (iii) esterification of hydroxyl groups to, e.g. phosphates, pyrophosphates or sulfates or hemi succinates, or (iv) formation of pharmaceutically acceptable salts, or (v) formation of pharmaceutically acceptable complexes, or (vi) synthesis of pharmacologically active polymers, or (vii) introduction of hydrophilic moieties, or (viii) introduction/exchange of substituents on aromates or side chains, change of substituent pattern, or (ix) modification by introduction of isosteric or bioisosteric moieties, or (x) synthesis of homologous compounds, or (xi) introduction of branched side chains, or (xii) conversion of alkyl substituents to cyclic analogues, or (xiii) derivatisation of hydroxyl group to ketales,

acetales, or (xiv) N-acetylation to amides, phenylcarbamates, or (xv) synthesis of Mannich bases, imines, or (xvi) transformation of ketones or aldehydes to Schiff's bases, oximes, acetales, ketales, enolesters, oxazolidines, thiozolidines or combinations thereof; and (b) formulating the product of said modification with a pharmaceutically acceptable carrier.

The various steps recited above are generally known in the art. They include or rely on quantitative structure-action relationship (QSAR) analyses (Kubinyi, 1993), combinatorial biochemistry, classical chemistry and others (see, for example, Holzgrabe and Bechtold, 2000).

In a another embodiment the invention relates to a method for producing a pharmaceutical composition, medical product, medical adjuvant or vaccine comprising formulating the product obtained by the above method of the invention with a pharmaceutically acceptable carrier and/or diluent.

Employing the data obtainable with the peptide of the invention, new immunostimulatory substances may be generated. The sequence of the peptide of the invention provided herein allows to design modified or alternative molecules with immunostimulatory activity. In one alternative, potential immunostimulatory substances may be tested for on natural NK cells. Those substances which, in cotreatment with IL-2 and/or IL-18, stimulate a proliferate response which is higher than the proliferative response to IL-2 and/or IL-18 alone are to be formulated into pharmaceutical compositions for the downstream development of immunostimulatory substances suitable for formulation into pharmaceutical compositions. The new stimulatory substances may be further refined by peptidomimetics or otherwise as is known in the art, i.a. depending on the specific medical purpose or route of administration or may be prepared as a fusion protein. The embodiments recited in this paragraph also belong to the present invention.

Preferred concentrations of IL-2 and/or IL-18 are in the range of 1ng - 1µg/ml.

Insofar, the invention relates also to a preferred method as stated above, wherein said product is refined by computer redesign and/or peptidomimetics.

In a still further embodiment the invention relates to the use of the peptide of the present invention the fusion (poly)peptide of the invention, the polynucleotide of the invention, the vector of the invention or the peptide refined by the method of the invention or to be formulated into a pharmaceutical composition produced by the method of the invention for the preparation of a pharmaceutical composition for the activation of NK cells.

The term “NK cells” ("natural killer cells") as used herein denotes large granular lymphocytes having CD45 surface expression and which furthermore have killer cell activity without previous stimulation. NK cells are especially characterized by epression of CD16 and/or by their susceptibility to Interleukin-2 stimulation and/or do not express CD3 and/or do not express α/β- γ/δ- T-cell receptors.

NK-cells of the present invention preferably are further characterized by the following characteristics:

- they are transiently plastic-adherent after stimulation with IL-2 in a dosage of 10 to 10.000 units, e.g. von 100 units, wherein IL-2 can be obtained from Chiron Corp.;
- Adherens can be observed 3-18 h after stimulation of previously isolated PBLs (Peripheral Blood Lymphocytes) with IL-2.;
- the NK cells express CD16dim (the mean value of fluorescence is weak);
- the NK cells express CD56 and CD57 as typical NK-markers;
- the NK-cells express CD94 (C-type lectin killer-cell- receptor);
- the NK-cells secrete IFNgamma after atcivation with Hsp70 and cytokines;
- the NK-cells can be activated (growth and cytotoxic activity) by Hsp70 (purified protein);
- they are not dependent on a patients MHC-type.

In the present invention different NK-cell populations can be applied. It is, however, required that the NK-cells as characterized herein can be activated by the peptide of the invention. It is possible to use isolated NK-cells but mixtures containing different

cell types like peripheral blood mononuclear cells (PBMC) also comprising NK cells can be applied too.

In a preferred embodiment said activation comprises the activation of the proliferation of NK cells and/or the cytolytic activity of NK cells.

In a final embodiment the invention relates to the use of the peptide of the invention the fusion (poly)peptide of the invention, the polynucleotide of the invention, the vector of the invention or the peptide refined by the method of the invention or to be formulated into a pharmaceutical composition produced by the method of the invention for the preparation of a pharmaceutical composition in immunotherapy and/or for the treatment of diseases selected from carcinomas of lung, colorectum, pancreas, larynx, stomach, peripheral and central nervous system, other carcinomas, sarcomas, chronic myeloic leukemia (CML), acute myeloic leukemia (AML), acute lymphatic leukemia (ALL), non Hodgkin Lymphoma (NHL), myeloproliferative syndrome (MPS), myelodysplastic syndrome (MDS), plasmocytoma, other leukemias, other malignant diseases, wherein Hsp70 is present on the surface of malignant cells, an infection with an HI virus, other viral or bacterial infections wherein Hsp70 is present on the surface of infected cells, rheumatoid arthritis, lupus erythematodes, other autoimmune diseases, asthma bronchiale, or other inflammatory diseases.

The figures show:

Figure 1.

Comparison of the proliferative response of NK cells against Hsp70 peptides. NK cells were stimulated either with IL-2 (100 IU/ml) alone or with IL-2 plus peptides NLL (8-mer, Figure 1a), TKD (14-mer, Figure 1b) and GIPP (13 mer, Figure 1c) at concentrations 0.02, 0.2, 2, 4 and 8 µg/ml. As a positive control NK cells were stimulated with rHsp70 protein at a concentration of 10 µg/ml. The proliferative response of NK cells was measured 72 h after peptide incubation and an 18 h incubation period with ^{3}H thymidine (1 µCi/ml). Stimulation with different peptides at a concentration of 2µg peptide per ml is shown in Figure 1d. In Figure 1e stimulation

with TKD in a more refined scale between 0.1 and 3 µg is shown. Figure 1f shows stimulation with various peptides. Values are given as the means of four independent experiments +/- SD.

Figure 2.

Cytolytic activity of NK cells stimulated with IL-2 alone or with IL-2 plus the 14-mer peptide TKD or with IL-2 plus the 8-mer peptide NLL. Cytolytic activity of NK cells either stimulated with low dose IL-2 (100 IU/ml) alone or with IL-2 plus the 14-mer peptide TKD (2 µg/ml) or with IL-2 plus the 8-mer peptide NLL (2 µg/ml) for 4 days. As target cells ^{51}Cr labeled CX+ (Figure 2a) and CX- (Figure 2b) tumor cells, that differ with respect to their capability to express Hsp70 on the plasma membrane, were used. The results are expressed as the percentage of specific lysis at varying E:T ratios ranging from 2:1 up to 40:1. The percentage spontaneous release for each tumor target cell line was less than 20%. A phenotypic characterization of the NK cells reveals the following: NK cells plus TKD: CD3, 6%; CD16/56, 79%; NK cells plus NLL: CD3, 8%; CD16/56 80%; NK cells: CD3, 5%; CD16/56: 81%.

The data represent one representative experiment out of three.

A better understanding of the present invention and of its many advantages will be had from the following examples, given by way of illustration.

Example 1

Epitope mapping analysis of the Hsp70 specific mAb

Previously, we showed an unusual plasma membrane localization of Hsp70 selectively on tumor cells with the Hsp70 specific mAb RPN1197 (Multhoff et al., 1995a/b; Botzler at al., 1996; Multhoff et al., 1997). This antibody also has been found to inhibit the cytolytic activity of cells against Hsp70 expressing tumor cells (Multhoff et al., 1995b). By using Hsp70 deletion mutants that either lack the C- or the N-terminal domain the binding epitope of the mAb RPN1197 could be localized within the C-terminal substrate binding domain of Hsp70 between aa 428-618 (Botzler et al., 1998). Due to the fact that RPN1197 exhibits an inhibitory effect on

the cytolytic activity of NK cells against Hsp70 expressing tumor cells it was of interest to map the binding epitope. By peptide scanning (pepscan) of the C-terminal substrate binding domain within aa 384-618 the 8-mer peptide NLLGRFEL (aa 454-461) could be determined as the relevant recognition structure for the mAb RPN1197 (Table I a).

Table I a.

Results of the pepscan analysis of the C-terminal domain of Hsp70 protein (aa 384 – 618); 13-mer peptides with an overlap of 11 peptides were tested. The region 444 – 471 is shown; positive pepspots are marked in bold.

Positive pepspots	Sequence region aa 444 – 471 of Hsp70 protein
aa 444-471	E G E R A M T K D N N L L G R F E L S G I P P A P R G V
aa 444-456	E G E R A M T K D N N L L
aa 446-458	- - - E R A M T K D N N L L G R
aa 448-461	- - - - - - A M T K D N N L L G R F E L
aa 450-463	- - - - - - - - - T K D N N L L G R F E L S G
aa 452-465	- - - - - - - - - - - - D N N L L G R F E L S G I P
aa 454-467	- - - - - - - - - - - - - - - N L L G R F E L S G I P P A
aa 456-469	- - - - - - - - - - - - - - - - - - L G R F E L S G I P P A P R
aa 458-471	- R F E L S G I P P A P R G V

Example 2

Analysis of the immunostimulatory capacity of different Hsp70 peptides

An incubation of NK cells with low dose IL-2 (100 IU/ml) plus recombinant human Hsp70 protein (rHsp70) or the C-terminal domain of Hsp70hom has been found to increase the proliferative response of human NK cells, as compared to NK cells that had been stimulated with IL-2 only (Multhoff et al. 1999). In an effort to define the minimal immunostimulatory sequence within the C-terminal domain of Hsp70, three peptides have been synthesized. Based on the 8-mer antibody binding epitope

(NLLGRFEL) of RPN1197 mAb, a C- (GIPP) and an N-terminal (TKD) extended peptide were produced to test them in a standard ^{3}H thymidine uptake assay. The C- and N-terminal extensions were in accordance to the primary sequence of human Hsp70 (Table I b).

Table I b.

Amino acid (aa) sequences of peptides that were used for NK stimulation assays.

Origin of protein	aa	Sequence	Name (length)
Hsp70	454-461	------N L L G R F E L	NLL (8-mer)
Hsp70	454-466	------N L L G R F E L S G I P P	GIPP (13-mer)
Hsp70	450-463	T K D N N L L G R F E L S G	TKD (14-mer)

As an internal control the proliferative capacity of NK cells against intact recombinant Hsp70 protein (rHsp70) was investigated. A concentration of 10 µg/ml of rHsp70 has been defined as an optimal stimulatory dose, previously (loc. sit). With respect to the molecular weight of the different peptides the concentration which is equivalent to 10 µg full length Hsp70 protein (72 kDa) was calculated as 0.2 µg/ml for TKD (1563 Da) and GIPP (1452 Da) and as 0.1 µg/ml for NLL (942 Da). With respect to these results all peptides were tested at a concentration range of 0.02 µg up to 8 µg/ml. As shown in Figure 1 the 8-mer peptide NLL and the C-terminal extended peptide GIPP did not stimulate the proliferative capacity of NK cells at any of the tested peptide concentrations. However, the N-terminal extended 14-mer peptide TKD exhibits a comparable immunostimulatory capacity like full length Hsp70 protein at a concentration range between 0.2 up to 2 µg/ml. This peptide concentration is comparable to a concentration of 10 –100 µg/ml of full length Hsp70 protein.

The proliferative response of T cells derived from the same donors was also tested against the peptides plus low dose IL-2 (100 IU/ml). As expected none of the three

peptides NLL, GIPP or TKD stimulates T cell growth at any of the tested concentrations (data not shown). However, experiments are in progress investigating the immune response of T cells against complexes consisting of rHsp70 protein and the Hsp70 peptides NLL, GIPP, TKD.

Since TKD appears to stimulate the proliferative activity of NK cells the question arises whether this peptide, similar to Hsp70 protein, also stimulates the cytolytic activity. The role of Hsp70 membrane expression as a tumor specific recognition structure for the cytolytic activity of NK cells was demonstrated with HLA identical colon carcinoma sublines CX+ and CX- that differ profoundly with respect to their capacity to express Hsp70 on the plasma membrane (14). In the present study the cytolytic response of NK cells stimulated for 4 days either with IL-2 alone (100 IU/ml) or with IL-2 plus NLL or IL-2 with TKD peptide (2 µg/ml) were compared. A phenotypic characterization of the effector cells was performed directly before stimulation and on day 4 after stimulation. The results are shown in the legend of Figure 2. IL-2 plus TKD stimulated NK cells exhibited a significantly enhanced lytic activity against Hsp70 expressing CX+ tumor cells compared to NK cells that were stimulated either with IL-2 alone or with IL-2 plus NLL peptide. However, no significant differences in lysis of CX- tumor cells was observed after stimulation with either of the peptides. This finding indicates that the immunostimulatory effects of the 14-mer TKD peptide on NK cells is Hsp70 specific.

Example 3

Comparison of NK stimulatory and non-stimulatory Hsp70 peptides and protein sequences

A comparison of the 14-mer stimulatory peptide sequence (TKD) of Hsp70 (indicated in bold) with the adequate region of Hsp70hom reveals one conservative amino acid exchange at position 462 from serin (S) to threonin (T) as shown in Table II.

Table II.

Comparison of the amino acid (aa) sequences of peptides and proteins with NK-

stimulatory and non-stimulatory capacity.

origin	aa	sequence	NK cell stimulation
Hsp70 (peptide)	454-461	- - - - - - N L L G R F E L (8mer peptide)	no
Hsp70 (peptide)	454-466	- - - - - - N L L G R F E L S G I P P (13mer peptide)	no
Hsp70 (peptide)	450-463	T K D N N L L G R F E L S G (14mer peptide)	yes
Hsp70 (peptide)	441-463	E G E R A M T K D N N L L G R F E L S G (20mer peptide)	yes
Hsp70hom (complete protein)	450-463	T K D N N L L G R F E L T G (complete protein)	yes
Hsc70 (complete protein)	450-463	T K D N N L L G K F E L T G (complete protein)	no
Dank (complete protein)	447-460	A A D N K S L G Q F N L D G (complete protein)	no

Since, both proteins Hsp70 and Hsp70hom and the 14-mer peptide TKD are able to stimulate NK cells the aa at position 462 seems to be not relevant for the stimulation of NK cells. In contrast, the conservative aa exchange at position 458 from arginine (R) to lysine (K) between Hsp70 and Hsc70 might be of importance since only Hsp70 but not Hsc70 is able to activate NK cells. Furthermore, this aa exchange might be responsible for the specificity of the Hsp70 specific antibody RPN1197. This antibody is known to react with Hsp70 but does not cross-react with Hsc70. The only aa difference of Hsp70 and Hsc70 within the 8-mer antibody binding epitope (aa 454-460) is the exchange at position 458 from arginine (R) to lysine (K).

In a further experiment that was scheduled as outlined above, only peptides were tested for their capacity to stimulate NK cells, see Table III, below. All these experiments allow the conclusion that amino acids TKDN in positions 450 to 453, R in position 458 and S in position 462 are crucial for the effectiveness of the peptide.

Table III

Comparison of the amino acid (aa) sequences only of peptides (but not proteins) with NK-stimulatory and non-stimulatory capacity. The immunostimulatory capacity of the different peptides was determined in ^{3}H thymidine uptake assays and ^{51}Cr release assays. Amino acid exchanges to the 14-mer stimulatory peptide are indicated in bold.

origin	aa	sequence	NK cell stimulation
Hsp70 (NLL)	454-461	- - - - - - N L L G R F E L	no
Hsp70 (GIPP)	454-466	- - - - - - N L L G R F E L S G I P P	no
Hsp70 (TKD)	450-463	T K D N N L L G R F E L S G	yes
Hsp70 (TKD12)	450-461	T K D N N L L G R F E L	no
Hsp70	445-463	G E R A M T K D N N L L G R F E L S G	yes
Hsp70hom (HOM)	450-463	T K D N N L L G R F E L T G	low
Hsc70 (Hsc70)	450-463	T K D N N L L G K F E L T G	no
Dnak (DNAK)	447-460	A A D N K S L G Q F N L D G	no

Conclusions

In summary these data provide evidence that not only full length Hsp70 protein or the C-terminal domain of Hsp70hom is able to stimulate proliferation and the cytolytic activity of NK cells against Hsp70 expressing tumor cells but also a 14-mer peptide which is part of the C-terminal domain of Hsp70. The sequence of the 14-mer peptide is an N-terminal extension of the 8-mer binding epitope of the Hsp70

specific antibody RPN1197. This mAb not only detects plasma membrane bound Hsp70 but also has been found to inhibit NK-mediated lysis against Hsp70-positive tumor cells. This is the first report that NK cells can be stimulated by a 14-mer peptide derived from the C-terminal region of Hsp70.

Recently, the existence of HSP specific receptors has been shown for antigen-presenting cells by internalization experiments of gold-labeled HSP and by confocal microscopy (Arnold-Schild et al., 1999; Asea et al., 2000). Functionally, we demonstrated that Hsp70 specific receptors also might exist on NK cells (Multhoff et al., 1999). Investigations are in progress to answer the question whether the14-mer peptide derived from the C-terminal domain of Hsp70 physically interacts with the Hsp70 specific receptor on NK cells.

Materials and Methods

Epitope mapping analysis

The monoclonal antibody RPN1197 reacts only with the inducible 72 kDa HSP, and is of similar reactivity to the antibody reported by Welch and Suhan (1986). Its specificity has been confirmed by immunoprecipitation of the 72 kDa protein from heat shocked cells. Epitope mapping analysis of mAb RPN1197 was perfomed using pepspot membranes with horseradish peroxidase conjugates and chemiluminescent luminol (Jerini Bio Tools GmbH, Berlin, Germany). Cellulose bound 13-mer peptides of the C-terminal domain of Hsp70 (aa 384-618) that exhibit an overlap of 11-mer peptides were used (Reineke et al., 1996).

Hsp70 and Hsp70 peptides

Human recombinant Hsp70 protein (rHsp70) was obtained from StressGen, Victoria, British Columbia, Canada (SPP-755). The 8-mer, 14-mer and 13-mer peptides NLLGRFEL (NLL), TKDNNLLGRFELS (TKD), NLLGRFELSGIPP (GIPP) were produced by the F-moc synthesis (fluorenylmethoxycarbonyl/ t-butyl-based solid-phase peptide chemistry method on SMPS 850 (Zinser Analytic) and ABI 488A (Perkin Elmer, Norwalk, Conn.) synthesizers. The purity of Hsp70 proteins and Hsp70 peptides was determined by the *Limulus* amebeocyte lysate assay (BioWhittaker, Maryland, USA).

NK cells

Briefly, monocyte depleted peripheral blood lymphocytes (PBL) were isolated from buffy coats of healthy human volunteers (Multhoff et al., 1995a). NK cells were purified by adherence selection following a modified protocol of Vujanovic (1993). T cells remain in the supernatant cell population.

FACScan analysis

Directly fluorescein-conjugated mAb ($CD3^{FITC}$/CD16/$CD56^{PE}$, Becton Dickinson, Heidelberg, Germany) were added to cell suspensions (0.1×10^6 cells), incubated for 20 min on ice, washed and analysed on a FACScan instrument (Becton Dickinson, Heidelberg, Germany). The percentage of positively stained cells was defined as the number of specifically stained, viable (propidium-iodide negative) cells minus the number of cells stained with an isotype matched control antibody on a FACScan instrument (Becton Dickinson, Heidelberg, Germany).

Tumor cell lines

The colon carcinoma sublines CX+ (>90% Hsp70 positive cells) and CX- (<20% Hsp70 positive cells) described in patent application EP -A2-084 300 5 and originally derived from CX2 colon carcinoma cells (Tumorzentrum Heidelberg, TZB 610005, Germany) that differ with respect to their capacity to express Hsp70 on their plasma membrane were cultured at 37°C, 5% CO_2 in RPMI-1640 medium (Gibco, Eggenstein, Germany) supplemented with heat-inactivated 10% FCS (Gibco) and 2 mM L-glutamine and antibiotics (penicillin/streptomycin). The cell lines were kept in culture under exponential growth conditions, and harvested with trypsin/EDTA solution. The experiments were performed between passage 10-30. All cell lines were free from mycoplasma contamination as determined by repeated testing using the 6-methylpurin desoxyribosid assay (Boehringer Mannheim, Germany).

^{3}H thymidine uptake assay

The proliferative capacity of NK and T cells against different Hsp70 peptides and Hsp70 protein (loc. sit) was determined in a standard ^{3}H thymidine uptake assay

(22). Viable cells (5×10^4 cells /100 µl) were seeded in 96-well flat-bottom microtiter plates (Greiner Nuertingen, Germany) in supplemented RPMI-1640 medium containing 100 IU IL-2 and Hsp70 protein (10 µg/ml) or different amounts of Hsp70 peptides ranging from 0.02 up to 10 µg/ml. As an internal control the proliferation against IL-2 alone was measured in parallel. After a 24 or 48 hour incubation period the cells were pulsed with ^3H thymidine (1 µCi/well) and the total uptake was measured following an 18 hour incubation period at 37°C in a liquid scintillation counter (Beckmann instruments, Munich, Germany).

Cell mediated lympholysis assay (CML)

The cytolytic activity of NK cells was monitored in a standard ^{51}Cr assay (23). Dilutions of the effector cells were incubated with ^{51}Cr-labeled (100 µCi of $Na^{51}CrO_4$, NEN-Dupont, Boston, MA) tumor target cells (3×10^3 cells per well) in duplicates at a final volume of 200 µl RPMI-1640 medium supplemented with 10% FCS at 37°C for 4 h in 96-well U-bottom plates (Greiner, Nuertingen, Germany). After the incubation period supernatants were collected and the radioactivity was counted in a γ-counter (Packard Instruments). The percentage of specific lysis was determined according to the equation: (experimental release – spontaneous release) / (maximum release - spontaneous release) x 100. The percentage spontaneous release was always <15% for each target cell line.

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CLAIMS

1. A peptide comprising or having the following amino acid sequence TKDNNLLGRFELXG wherein X is T or S
or a fragment or derivative thereof.

2. The peptide of claim 1 comprising or having the amino acid sequence EGERAMTKDNNLLGRFELXG wherein X is T or S
or a fragment or derivative thereof..

3. A fusion (poly)peptide comprising the peptide of claim 1 or 2.

4. A polynucleotide encoding the peptide of claim 1 or 2 or the fusion polypeptide of claim 3.

5. The polynucleotide of claim 5 which is DNA.

6. A vector comprising the DNA of claim 5.

7. A method of refining the peptide of claim 1 or 2 comprising
   (a) modeling said peptide by peptidomimetics; and
   (b) chemically synthesizing the modeled peptide.

8. A composition comprising the peptide of claim 1 or 2 or a fragment or derivative thereof, the fusion (poly)peptide of claim 3, the polynucleotide of claim 4 or 5, the vector of claim 6 or a peptide refined by the method of claim 7 and a pharmaceutically acceptable carrier and/or diluent.

9. The composition of claim 8 which is a pharmaceutical composition, medical product, medical adjuvant or vaccine.

10. A method of producing a immunostimulatory peptide comprising

(a) mutating on the DNA or amino acid level a DNA molecule encoding or peptide comprising the sequence TKDNNLLGRFELXG, wherein X is T or S, in one or more nucleotide or amino acid positions;
(b) testing the proliferative response of NK cells to stimulation with IL-2 and/or IL-18 together with the mutated peptide;
(c) comparing the proliferative response of NK cells to IL-2 and/or IL-18 together with the mutated peptide to the proliferative response to IL-2 and/or IL-18 without the mutated peptide or with a peptide having the sequence recited in (a);
(d) selecting a peptide comprising the mutated sequence or a recombinant DNA molecule coding for a peptide comprising the mutated sequence, wherein said mutated peptide displays an increase in the proliferative response as compared to IL-2 and/or IL-18 without the mutated peptide or with a peptide having the sequence recited in (a) in step (c).

11. The method of claim 10, wherein the product is refined by computer redesign and/or peptidomimetics.

12. A method for producing a pharmaceutical composition, medical product, medical adjuvant or vaccine comprising formulating the product selected by the method of claim 10 or 11 with a pharmaceutically acceptable carrier and/or diluent.

13. A method of producing a pharmaceutical composition comprising a molecule stimulating the activation of NK cells comprising the steps of
(a) modifying the peptide of claim 1 or 2 as a lead compound to achieve
(i) modified site of action, spectrum of activity, organ specificity, and/or
(ii) improved potency, and/or
(iii) decreased toxicity (improved therapeutic index), and/or
(iv) decreased side effects, and/or
(v) modified onset of therapeutic action, duration of effect, and/or
(vi) modified pharmakinetic parameters (resorption, distribution,

metabolism and excretion), and/or

(vii) modified physico-chemical parameters (solubility, hygroscopicity, color, taste, odor, stability, state), and/or

(viii) improved general specificity, organ/tissue specificity, and/or

(ix) optimized application form and route

by

(i) esterification of carboxyl groups, or

(ii) esterification of hydroxyl groups with carbon acids, or

(iii) esterification of hydroxyl groups to, e.g. phosphates, pyrophosphates or sulfates or hemi succinates, or

(iv) formation of pharmaceutically acceptable salts, or

(v) formation of pharmaceutically acceptable complexes, or

(vi) synthesis of pharmacologically active polymers, or

(vii) introduction of hydrophilic moieties, or

(viii) introduction/exchange of substituents on aromates or side chains, change of substituent pattern, or

(ix) modification by introduction of isosteric or bioisosteric moieties, or

(x) synthesis of homologous compounds, or

(xi) introduction of branched side chains, or

(xii) conversion of alkyl substituents to cyclic analogues, or

(xiii) derivatisation of hydroxyl group to ketales, acetales, or

(xiv) N-acetylation to amides, phenylcarbamates, or

(xv) synthesis of Mannich bases, imines, or

(xvi) transformation of ketones or aldehydes to Schiff's bases, oximes, acetales, ketales, enolesters, oxazolidines, thiozolidines

or combinations thereof; and

(b) formulating the product of said modification with a pharmaceutically acceptable carrier.

14. Use of the peptide of claim 1 or 2, the fusion (poly)peptide of claim 3, the polynucleotide of claim 4 or 5, the vector of claim 6 or of a peptide refined by the method of claim 7 or 11 or to be formulated into a pharmaceutical composition

produced by the method of claim 12 or 13 and a pharmaceutically acceptable carrier and/or diluent for the preparation of a pharmaceutical composition for the activation of NK cells.

15. The use of claim 14 wherein said activation comprises the activation of the proliferation of NK cells and/or the cytolytic activity of NK cells.

16. Use of the peptide of claim 1 or 2, the fusion (poly)peptide of claim 3, the polynucleotide of claim 4 or 5, the vector of claim 6 or of a peptide refined by the method of claim 7 or 11 or to be formulated into a pharmaceutical composition produced by the method of claim 12 or 13 and a pharmaceutically acceptable carrier and/or diluent for the preparation of a pharmaceutical composition for use in immunotherapy and/or for the treatment of diseases selected from carcinomas of lung, colorectum, pancreas, larynx, stomach, peripheral and central nervous system, other carcinomas, sarcomas, chronic myeloic leukemia (CML), acute myeloic leukemia (AML), acute lymphatic leukemia (ALL), non Hodgkin Lymphoma (NHL), myeloproliferative syndrome (MPS), myelodysplastic syndrome (MDS), plasmocytoma, other leukemias, other malignant diseases, wherein Hsp70 is present on the surface of malignant cells, an infection with an HI virus, other viral or bacterial infections wherein Hsp70 is present on the surface of infected cells, rheumatoid arthritis, lupus erythematodes, other autoimmune diseases, asthma bronchiale, or other inflammatory diseases.

Fig. 1a

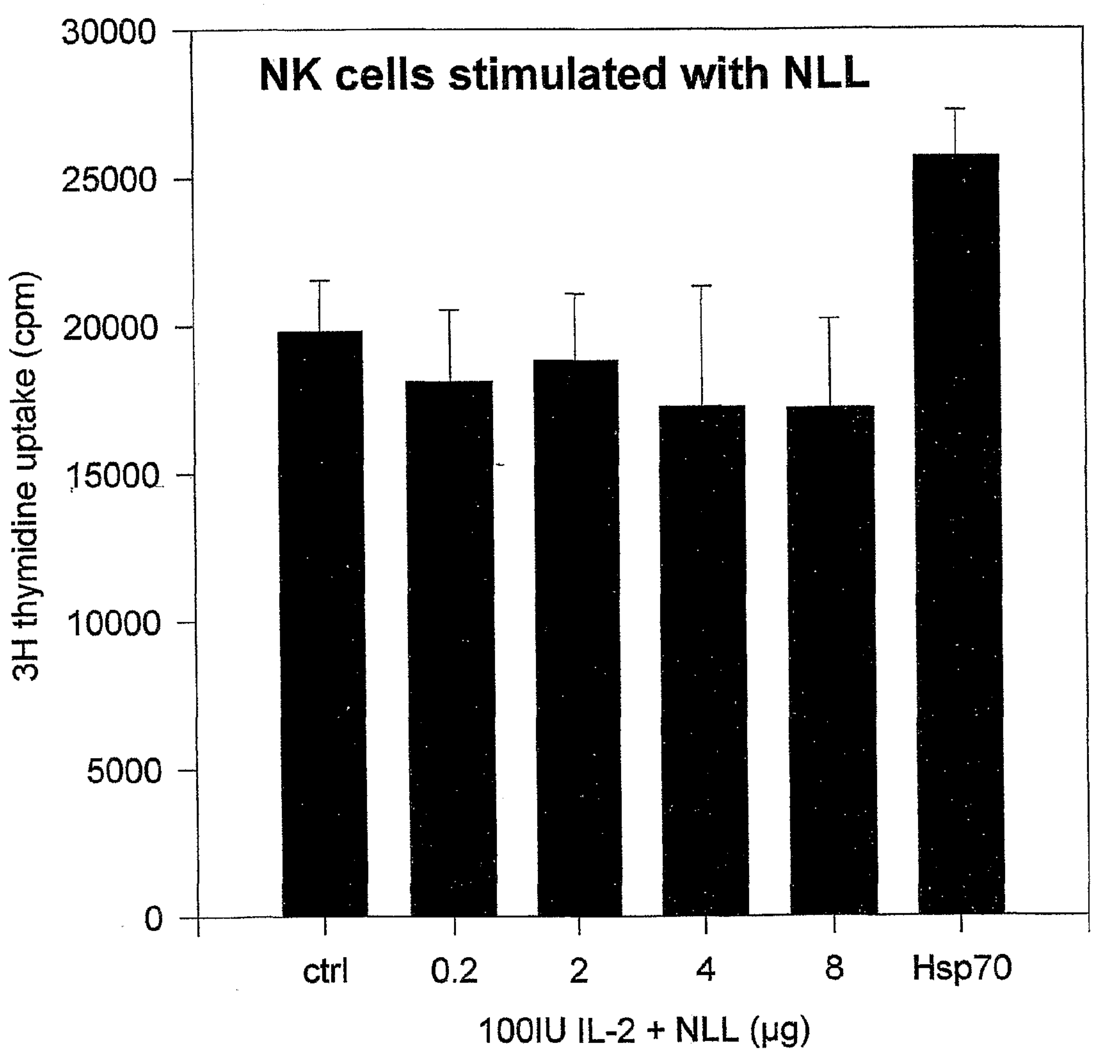

NK cells stimulated with NLL
3H thymidine uptake (cpm)
30000
25000
20000
15000
10000
5000
0
ctrl
0.2
2
4
8
Hsp70
100IU IL-2 + NLL (µg)

Fig. 1b

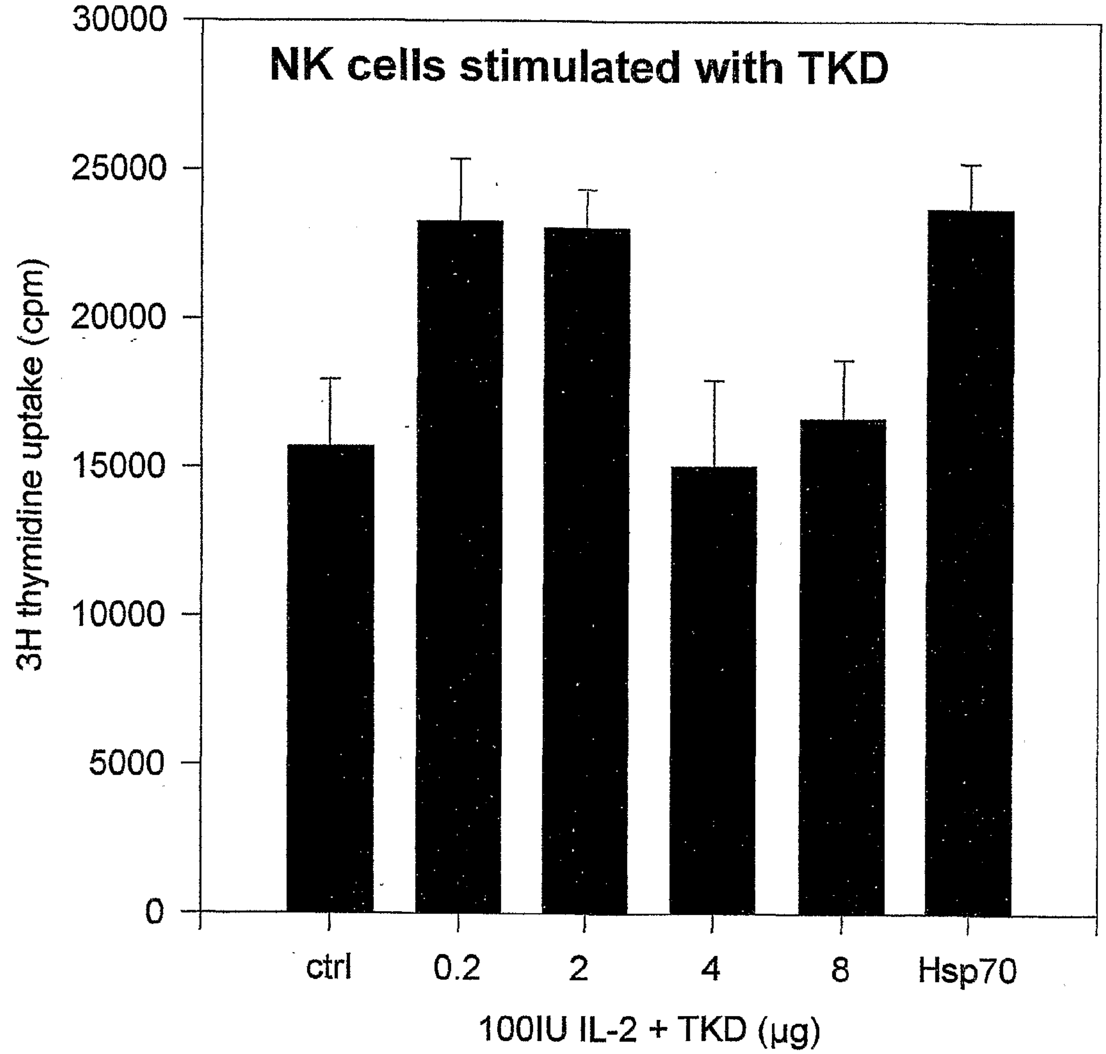

NK cells stimulated with TKD
3H thymidine uptake (cpm)
30000
25000
20000
15000
10000
5000
0
ctrl
0.2
2
4
8
Hsp70
100IU IL-2 + TKD (µg)

Fig. 1c

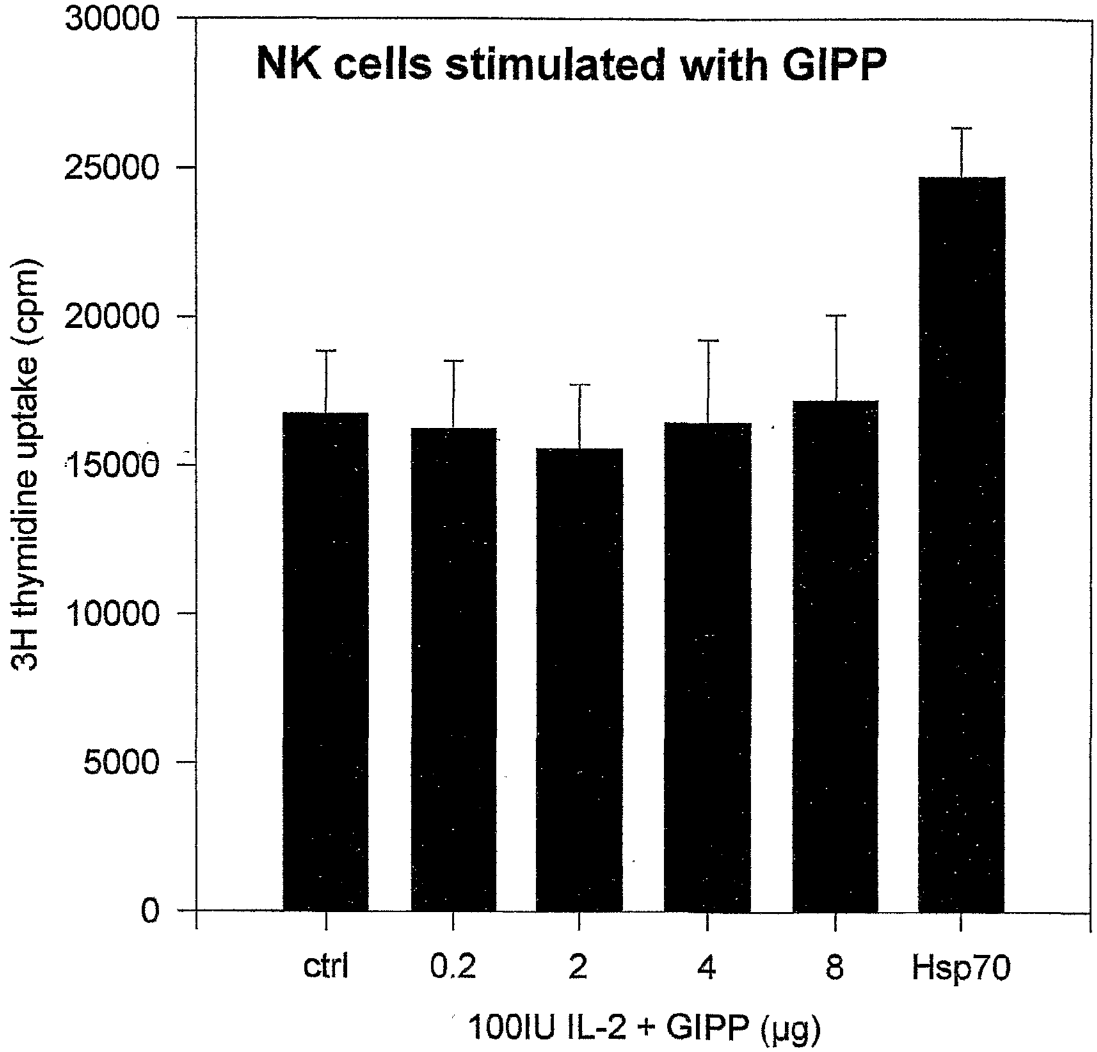

NK cells stimulated with GIPP
3H thymidine uptake (cpm)
30000
25000
20000
15000
10000
5000
0
ctrl
0.2
2
4
8
Hsp70
100IU IL-2 + GIPP (µg)

Fig. 1d

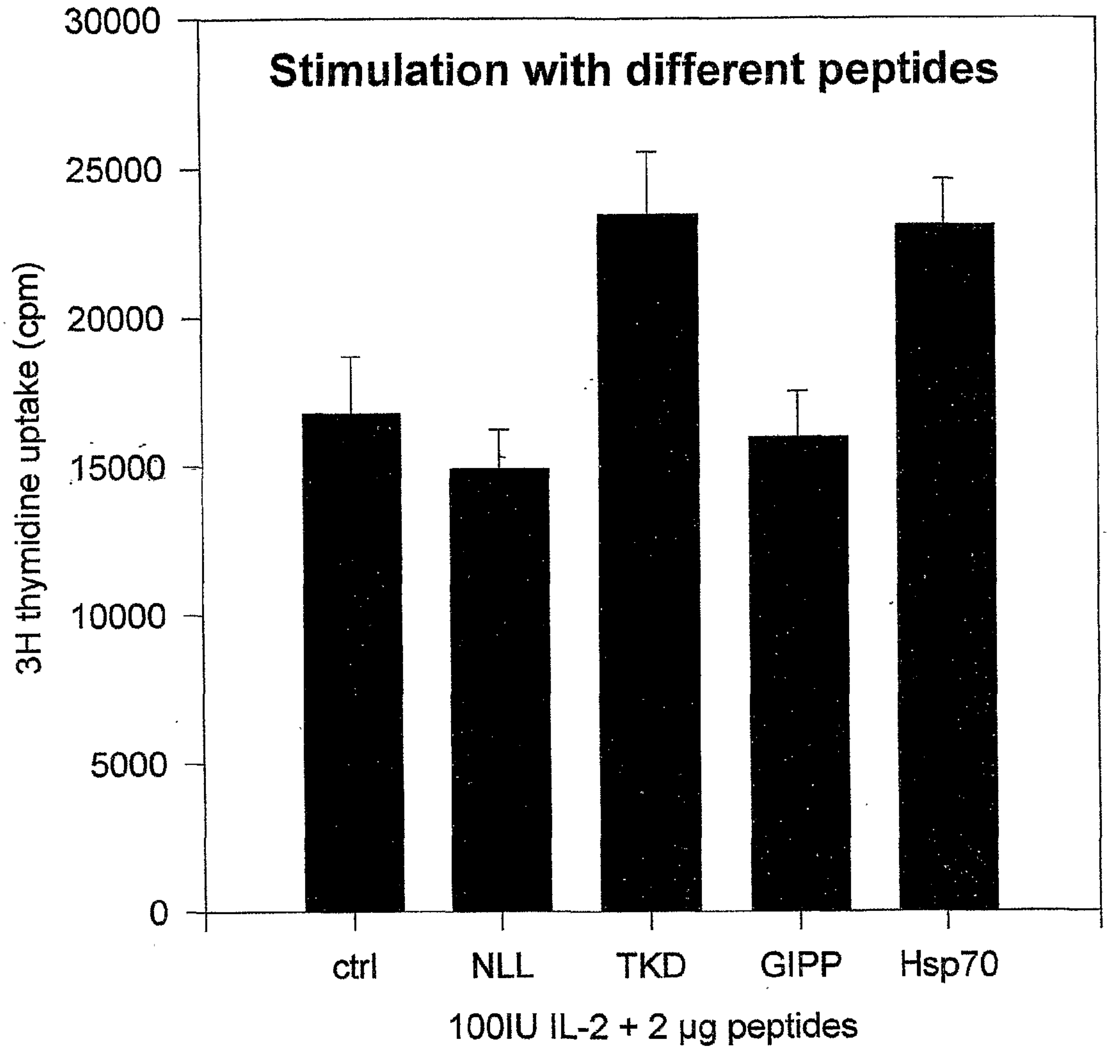

Stimulation with different peptides
3H thymidine uptake (cpm)
30000
25000
20000
15000
10000
5000
0
ctrl
NLL
TKD
GIPP
Hsp70
100IU IL-2 + 2 µg peptides

Fig. 1e

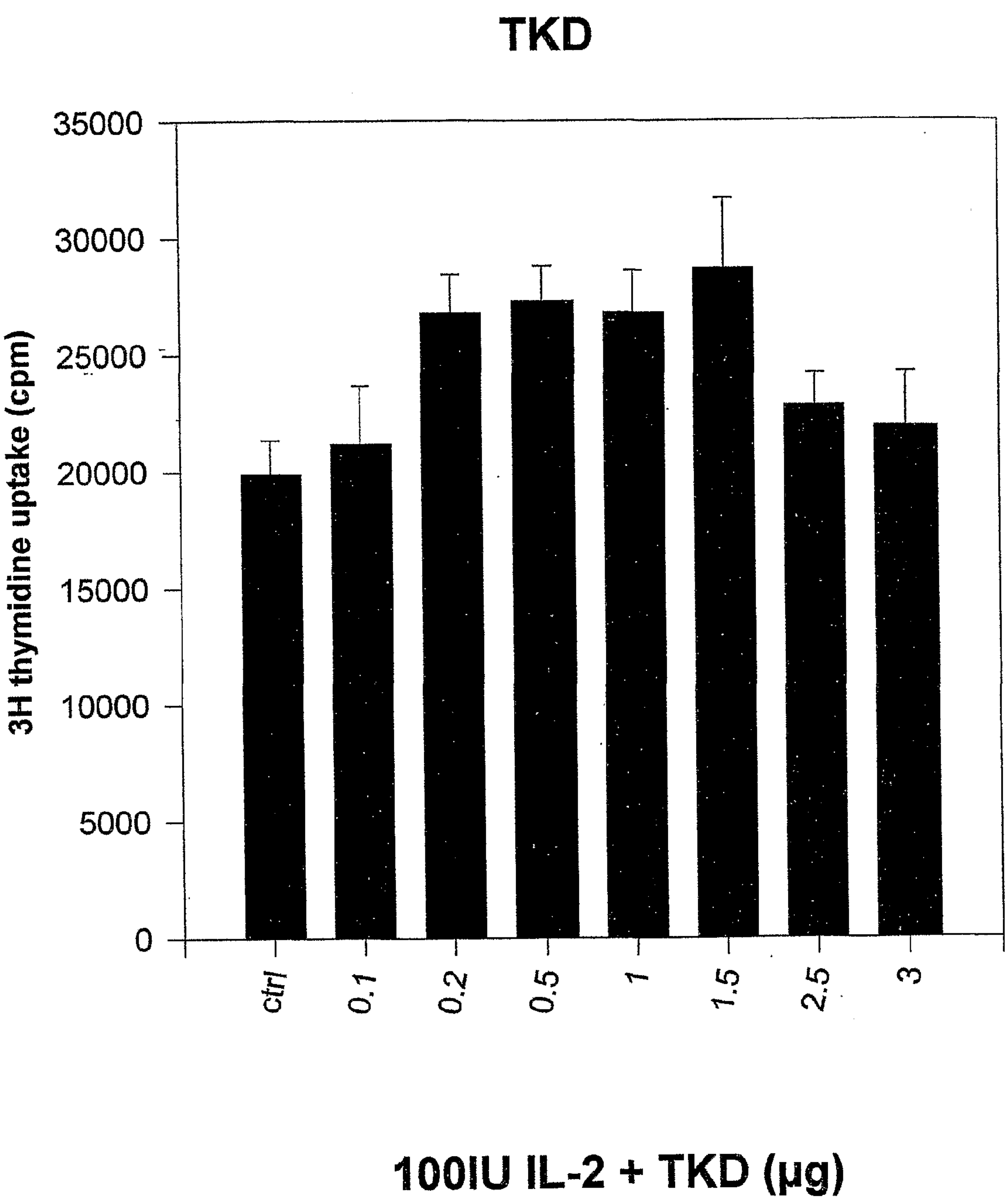

TKD
35000
30000
25000
20000
15000
10000
5000
0
3H thymidine uptake (cpm)
ctrl
0.1
0.2
0.5
1
1.5
2.5
3
100IU IL-2 + TKD (µg)

Fig. 1f

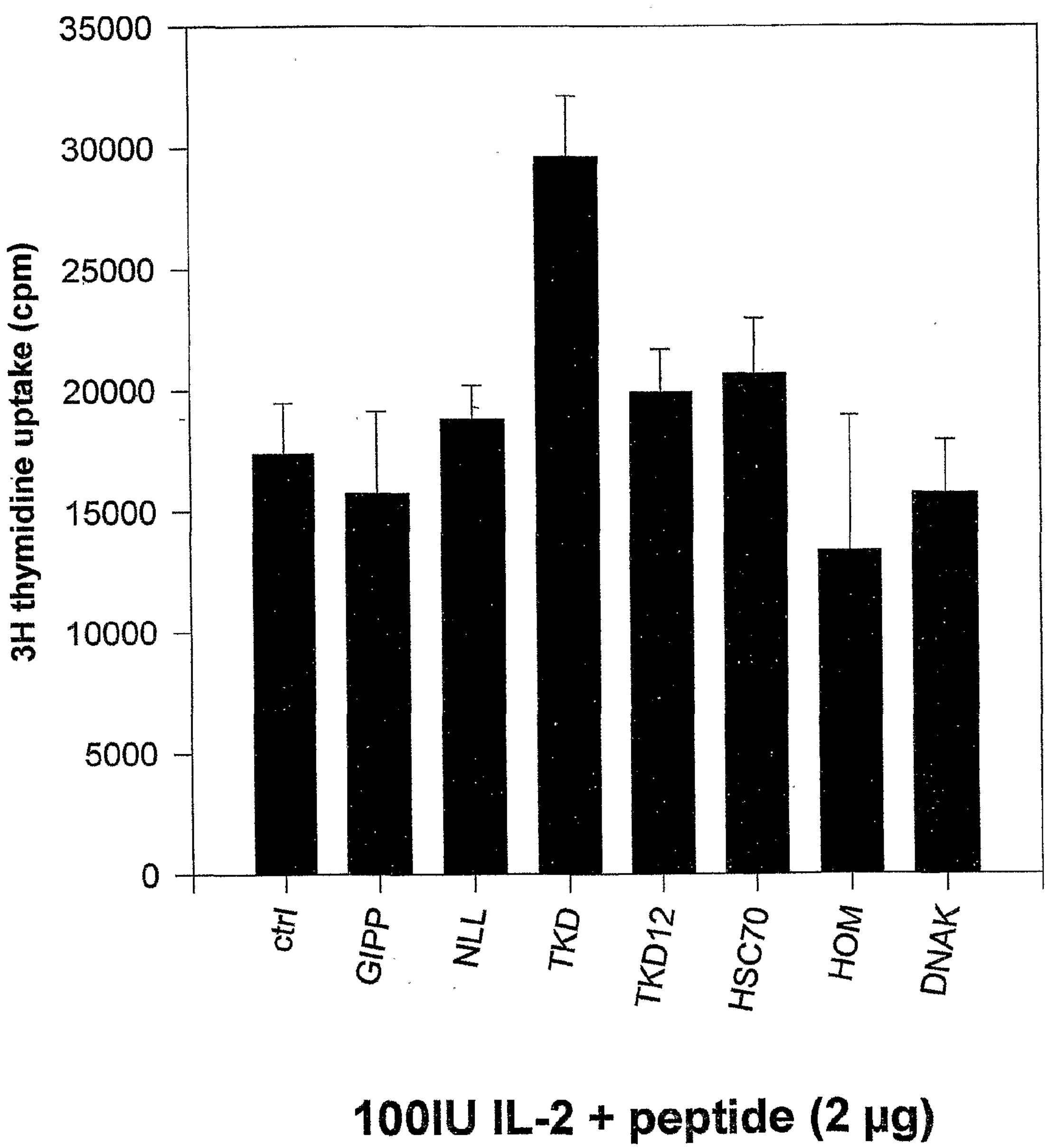

35000
30000
25000
20000
15000
10000
5000
0
3H thymidine uptake (cpm)
ctrl
GIPP
NLL
TKD
TKD12
HSC70
HOM
DNAK
100IU IL-2 + peptide (2 µg)

Fig. 2a

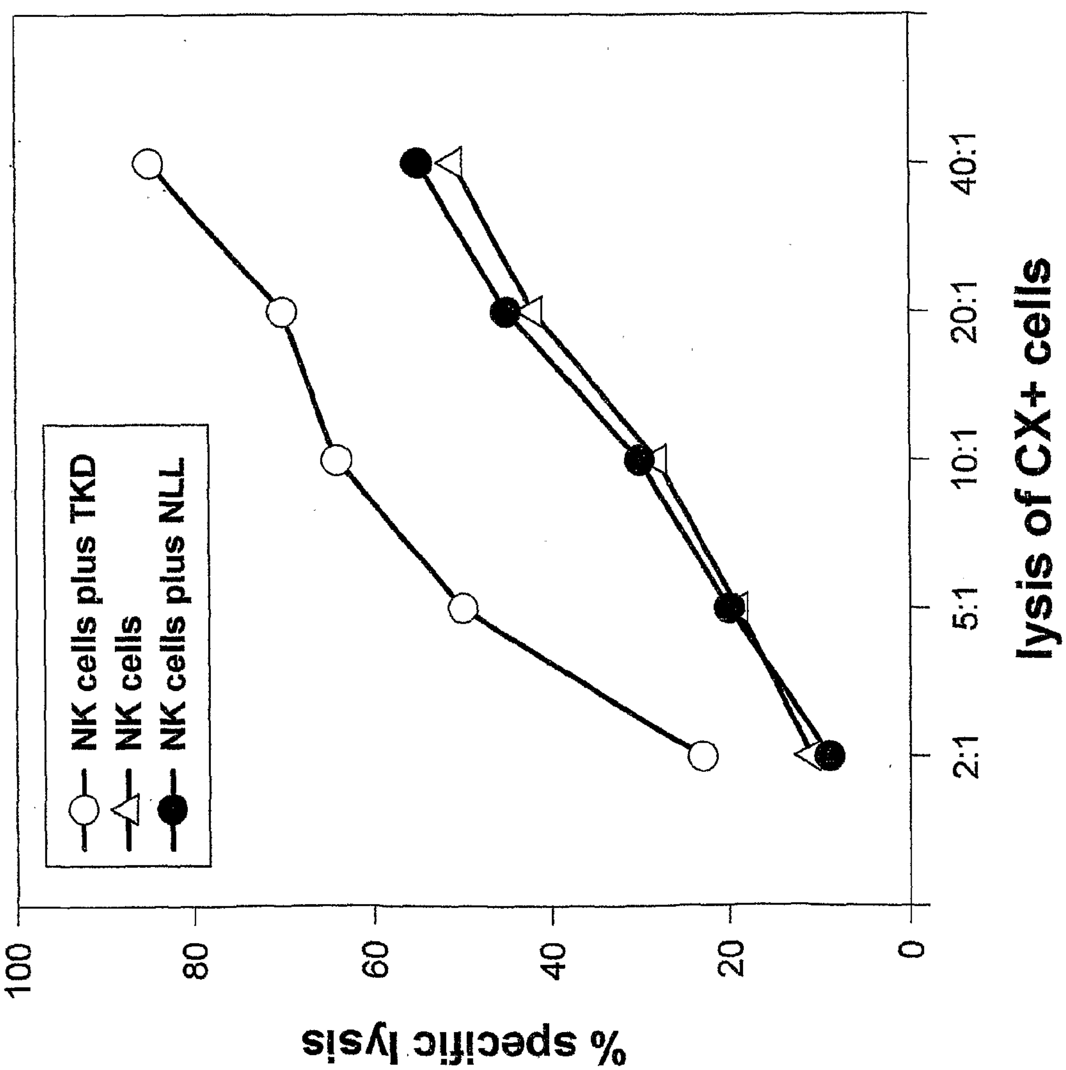
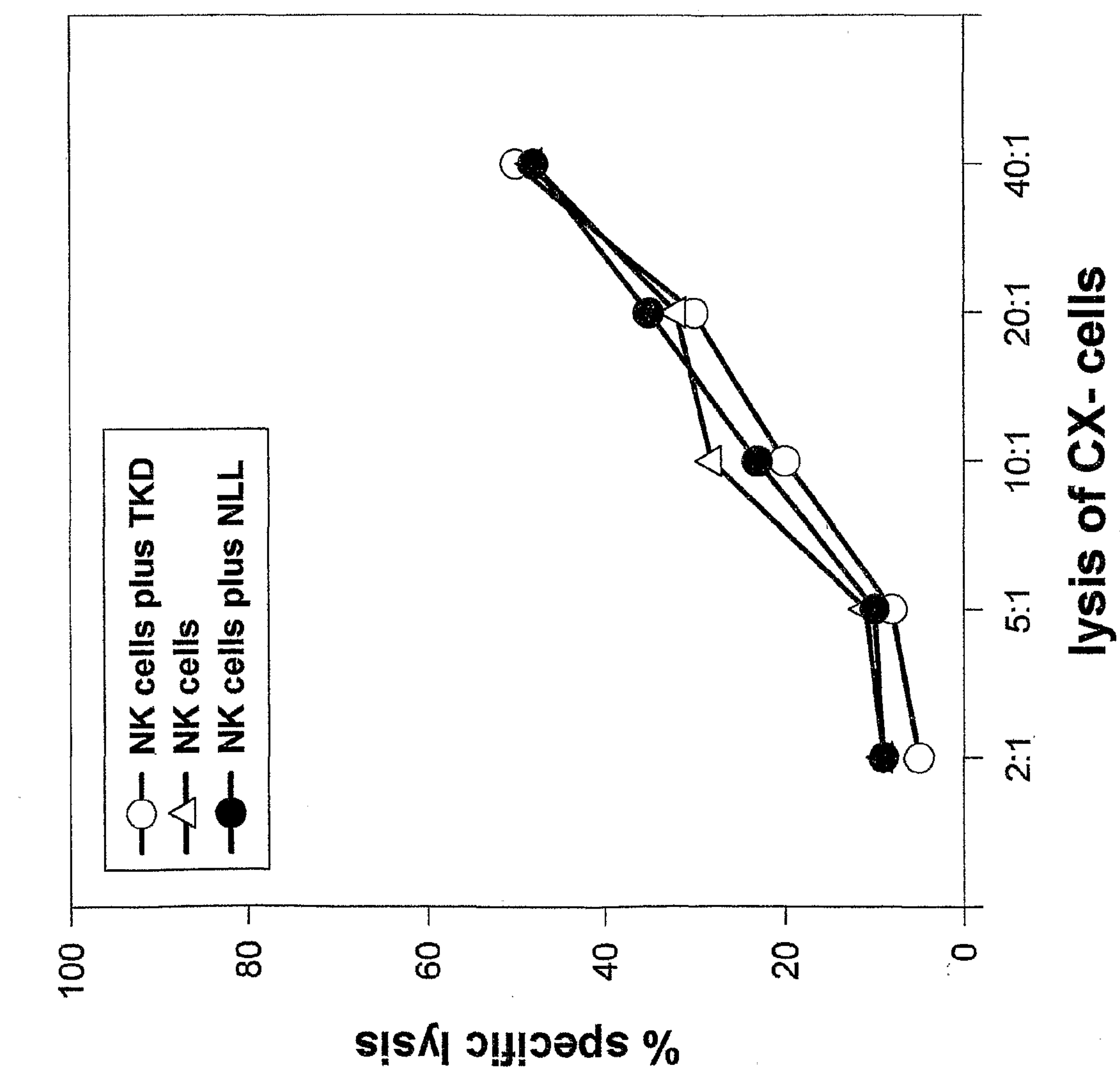

NK cells plus TKD
NK cells
NK cells plus NLL
% specific lysis
0
20
40
60
80
100
2:1
5:1
10:1
20:1
40:1
lysis of CX+ cells

Fig. 2b


NK cells plus TKD
NK cells
NK cells plus NLL
% specific lysis
100
80
60
40
20
0
2:1
5:1
10:1
20:1
40:1
lysis of CX- cells